Notes from neimagazine.com
-Two designs of the VVER reactor are V-392M and V-491
-V-392M for Novovoronezh(Moscow)
-V-491 for Leningrad(St. Petersburg)
-Passive safety systems prevail in the new modernised V-392M
-V-491 design focuses on active safety systems
-V-392M has two channels, while V-491 has four channels for active safety systems
-V-392M has focus placed on avoidance of redundancy aiming at higher cost-effectiveness
-V-392M and V-491 designs include a **common emergency core cooling system (ECCS) passive section**
-V-392M design the ECCS active section is represented by a combined two-channel high and low pressure system
-V-491 design utilizes a segregated four-channel high and low pressure system
-ATWS accident consequences are managed by a two-channel **emergency boron injection system** in the V-392M design and a four-channel system in the V-491 design
-Unlike the traditional four-channel emergency feedwater system that is used in the V-491 design, the **V-392M design features a closed two-channel steam generator (SG) emergency cooldown system.**
-To mitigate consequences of beyond design basis accidents involving total loss of alternating current sources, both designs use a passive heat removal system, which is air-cooled in the V-392M and water-cooled in the V-491. Additionally, **the V-392M design is fitted with a four-channel emergency passive core flooding system.**
-Are passive core flooding systems part of ECCS?Answer:Yes
-What does 1st stage and 2nd stage hydro accumulator mean?Actuates at diff pressure 5.9 & 1.5MPa
-How does SG emergency cooldown system work?
-What is AES-2006?

The differences between these V-392M and V-491 versions relate to:
-The system of passive heat removal from the containment, and the system of passive heat removal via steam generators [V-491];

- A passive core flooding system [V-392M];
- Active systems for high pressure emergency injection system and for low pressure emergency injection [V-491];
- Systems to cope with beyond design basis accidents;
- Predicted core damage frequencies;
- Differences in the I&C system, the feedwater system, and in the layout of the main control room; and
- Plant layout changes.

The combination of using active and passive systems to perform safety functions was adopted during development of an AES-92 reference design that served as a basis for Kudankulam NPP (India) project, and has been included in the AES-2006 and VVER-TOI NPP designs.

-To ensure emergency heat removal from the core by passive safety systems, the plant is provided with a passive heat removal system (PHRS) and a system of water tanks (‘hydraulic accumulators’) in a first and second stage (HA-1 and HA-2)

-If a loss of all AC power sources(SBO) at the site causes an active safety system failure, and that failure is not accompanied by a loss of coolant from the reactor circulation circuit, operation of the passive heat removal system alone will be sufficient to cool the reactor. Owing to the use of air as an ultimate heat sink, **the PHRS can perform its function for an unlimited period of time in these conditions**

-To cope with leakage of primary coolant(LOCA) accompanied by failure of active safety systems, sufficient reactor cooling will be provided by water tanks of the first stage in operation to flood the reactor vessel. Operation of the second-stage tanks and of the PHRS is necessary for long-term heat removal from the core. **In this case, the PHRS uses the steam generators (SG) to condense primary circuit steam from the reactor. Due to this, the steam generator condensate goes back to the primary circuit to complement water supplied by the second-stage tanks.Really????????**

-Considering the condensing ability of the steam generators, water inventory in the HA-2 tanks was chosen so that coolant inventory essential for reliable cooling of fuel can be maintained in the reactor vessel for 24-280 hours (depending on leak size). To make the reactor self-sufficient in case of any leakage, including a break in the main circulation pump, it is possible to use additionally the water from the spent fuel storage pool for at least 72 hrs (an extra inventory of about 800 m3).

-In an initiating event involving loss of all AC power sources(SBO) without the loss of primary coolant, **PHRS operation is not limited in time** and does not require any special accident management actions.

-The second stage water tanks (hydraulic accumulators) are intended to inject boric acid into the core for at least 24 hours in case of a maximum two-side loss of coolant in the primary circuit (stored concentration: 16g/kg).The system is actuated in the event of a loss of coolant in the primary circuit and pressure decrease in the reactor to ? =1.5 MPa.

-**The system consists of four water tank sets**. Each set comprises two tanks with drain pipes providing profiling of coolant flow. Coolant flows to the reactor from HA-2 due to the hydrostatic pressure. On the side of the drain line, the second stage tanks (HA-2) are hooked to the pipelines connecting the first stage tanks (HA-1) to the reactor. The upper part of the HA-2 tanks is connected, via special check valves, to the cold legs of the main circulation pipelines, in the immediate vicinity of the SG headers. Special check valves are set to open in case of circuit pressure decrease to 1.5 MPa.

-In abnormal conditions involving the coolant loss from the primary circuit, as the reactor pressure falls, first water tanks of the first stage start up (at ? < 5.9 MPa), and then second-stage tanks come into play (at ? < 1.5 MPa).

-HA-2 injects solution in four stages of 40, 20, 13.2 and 7.1 kg/s flow, each of varying duration, over 24 hours.

PHRS

-The passive heat removal system is designed to provide a long-term removal of residual heat from the reactor in case of a beyond-design-basis accident involving the loss of all AC power sources. **In the event of a loss of coolant from the primary circuit, the system provides removal of residual heat together with water tanks of the second stage.(LOCA+SBO)**

-The system consists of four independent trains; one per each steam generator. Each train comprises two heat exchangers/condensers, steam condensate pipelines with valves, air ducts with air shutters and a controller.

-Steam comes to the PHRS heat exchanger from a pipeline of each SG. Steam is condensed in the heat exchangers by atmospheric air. The air is taken from the atmosphere outside the containment building. Owing to natural draft, the air goes into a ring header running around the containment building. After that, air goes to heat exchanger modules via individual air ducts. Air condenses steam in the heat exchanger modules and goes into the draft shafts, which end in a common header with a deflector.

-While on standby, the heat exchangers of the system are warmed to the secondary circuit temperature, which rules out thermal cycling on PHRS initiation and provides the best dynamics for PHRS to pick up its rated capacity. Upstream and downstream of each PHRS heat exchanger module are closed gate valves that open on a loss-of-power signal. The valves serve to protect the equipment against an air shock wave and minimize heat losses at the unit while the system is on standby.

-The VVER-TOI design uses RVK-type passive catalytic recombiners of hydrogen (whose efficient flame-free operation has been substantiated for bulk hydrogen concentrations ranging from 0.45% to 16%. A total of 160 passive catalytic burners are installed across the containment. Owing to this, average bulk concentration of hydrogen in the containment should not exceed 6%, protecting the plant from hydrogen explosions in design-basis and beyond-design-basis accidents.

Conclusion:

The passive technologies discussed above are specific to AES-92, AES-2006 and VVER-TOI designs developed by Atomenergoproekt. They are not present in any other designs of operating NPPs or plants currently under construction. The design characteristics of these passive safety systems, confirmed in the tests performed at large-scale experimental facilities, prevent – with high degree of certainty – fuel damage above the design limits for at least 72

hours in case of a beyond-design-basis accident involving loss of coolant from the primary circuit, and during a greater period (up to 10 days) in the event of the loss of all AC sources that is not accompanied by coolant leakage. The engineering solutions used in the passive safety systems design allow further upgrading to prolong plant self-sufficiency in any initiating events, including those which are very unlikely.

Notes from http://www.bfdr-bd.com/bangladesh-entering-nuclear-club/

In 2014 Moscow AEP said that the plant would be an AES-2006 with a version of its V-392M reactors, with Novovoronezh II being the reference plant. Turbine generators (high speed) are expected to be from Power Machines.

Planned nuclear power reactors

	Type	Capacity	Construction start	Commercial operation
Rooppur 1	**VVER-1200/V-523**	**1200 MWe**	**Oct 2017**	**2023 or 2024**
Rooppur 2	**VVER-1200/V-523**	**1200 MWe**	**2018**	**2024 or 2025**

Notes from Fukushima:

Safety of the new VVER design is ensured by consistent implementation of the DiD. For example, at the **first level of DiD** in AES-2006 design (in particular, units of Novovoronezh NPP-2) the following measures are provided:

- robustness of NPP towards external impacts;

- minimization of size of the potential radiation impact zones of NPP on the population during normal operation and accidents;

- development of the design by basing it on a conservative approach with mature intrinsic safety of the reactor installation . Including:-

-self-control of reactor power

- maintaining primary pressure at the expense of negative reactivity and pressure feedback,

-Ability to remove heat from the core of the shutdown reactor to the ultimate heat

sink by natural circulation

-large inventory of water in horizontal steam generators and other vessels;

and

-effective system of maintenance and repair.

Second level of DiD:

As part of the **second level of DiD**, the new VVER designs provide for engineered features

(means of diagnostics, automatic controllers, interlocks, automatic protection features and

others) which allow timely identification of and correction to departures from normal operation,as well as exercise control in case of such departures.

Third level of DiD:

At the third level of DiD, the AES-2006 design has a balanced combination of **active and passive safety systems.** Such a combination ensures both quick (due to active part) and reliable (due to passive part) mitigation of **design basis accidents and BDBAs** that may occur.

Active safety systems:

Active safety systems are of a 2-train configuration with internal redundancy (Novovoronezh NPP-2) or a 4-train configuration (Leningrad NPP-2).It includes the following:

-Emergency reactor protection system, (Shutdown System)

-Protection systems of the primary and secondary circuit against overpressure (these systems remain functional when the power is lost),

-A System for emergency and scheduled cooldown of the primary circuit and cooling of spent fuel pool,

-Emergency boron injection system, (Shutdown System)

-Emergency steam generator cooldown system,

-Emergency power supply system,

-Spray system.Why do we need it??

-Emergency gas evacuation system and others

Q:Why is the spray system used?

A:The spray system is intended in the event of an accident to reduce pressure and temperature inside the containment and bind radioactive iodine which will be present in the steam and air of the containment. This system ensures automatic injection of borated water into the air of the containment when pressure within the containment exceeds a certain value and ceases when it decreases down to a certain value.

Passive Safety System:

The passive safety systems includes the following:

-Passive heat removal system from the SGs(PHRS SG)

-Passive core flooding system (hydro accumulators).The passive safety systems in the AES-2006 design also includes a double-walled containment.

-The passive core flooding system (hydro accumulators) for Novovoronezh NPP-2 consist of 4 accumulator tanks (AT) of the 1st stage and 8 ATs of the 2nd stage. The operation of the system provides for cooling of the core during, as a minimum, 24 hours when active safety systems fully fail and the primary pipeline suffers a guillotine break.

Fourth Level of DiD:

To manage beyond design basis accidents (including severe accidents - Level 4 DiD) the VVER designs include the following engineered features and organizational measures in addition to that used at Level 3:

- passive heat removal system;

- containment hydrogen removal system;

- corium retention and cooling system (core catcher);

Q:How does the core catcher work???

A:The core catcher (CC) in the AES-2006 design is intended to localize corium constituents and core fragments, to ensure cooling of molten corium and its subcriticality, and to minimize release of radioactive substances and hydrogen inside the containment.

The heat removal from Core Catcher is by passive heat transfer to cooling water surrounding the “core melt pot” and is capable of ensuring long term cooling and solidification of the molten core. The sacrificial material of the CC includes gadolinium oxide to ensure subcriticality of the molten core. The hydrogen generation decreases significantly (about factor 4) in the CC due to the hot metal capturing oxygen from the aluminum oxide in the pot instead of from water. A crust formed on top of the melt surface minimizes release of radionuclides into the containment.

VVER Design features to cover specific BDBA/DEC :

The distinctive feature of the new VVER designs is application of passive heat removal systems (PHRS) to provide for basic safety functions at the initial period of BDBA with SBO (loss of

UHS).

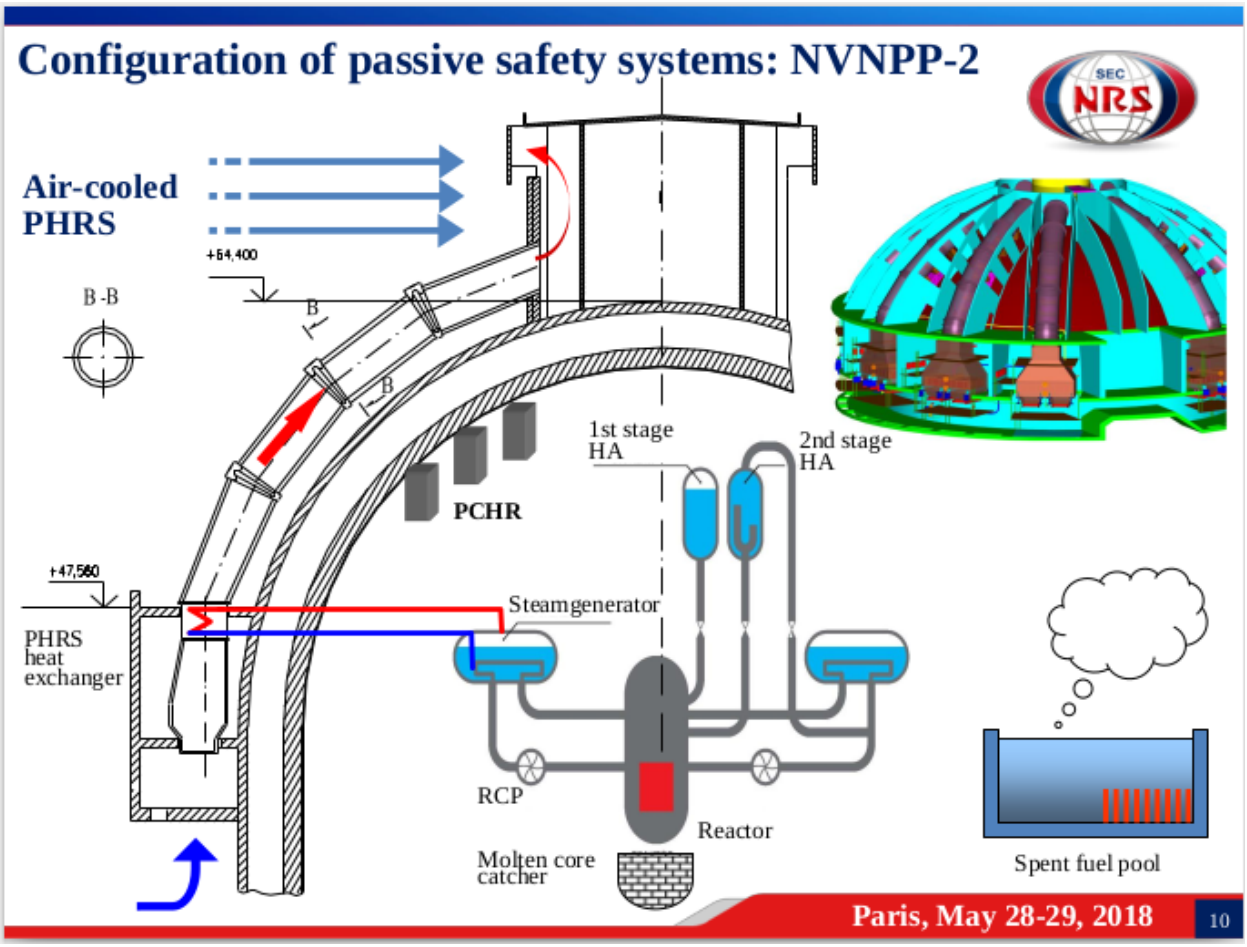
There are two types of steam generator PHRSs:

1)Air-cooled (Novovoronezh-2 NPP with AES-2006-M and VVER-TOI in Russia, Kudankulam NPP with VVER-1000 in India) and

2)Water-cooled (Leningrad-2 NPP with AES-2006-P).

Q: How does the Air-cooled SG PHRS work?

A: The air-cooled PHRS uses air as the UHS. The reactor residual heat is transferred through steam generators to steam-external air heat exchangers of the PHRS where the steam is condensed and returned to the steam generators. Cold air intake is in the lower part of the reactor building.

Heated air conveys through air ducts on the dome of the containment to discharge deflector. If primary circuit is intact, the heat can be removed for considerable time without external water makeup. In case of leaky primary circuit, the heat removal is secured by joint operation of PHRS and 2nd stage hydro accumulators (2 nd stage hydro accumulators in case of Kudankulam VVER- 1000 and AES-2006-M design and 2nd and 3rd stages hydro accumulators in case of VVER-TOI design).

Configuration of passive safety systems: NVNPP-2